Effect of welding parameters, carbon equivalent, preheat, inter-pass & post weld requirement

1.0 INTRODUCTION:

Adherence to some basic procedures is mandatory to achieve the desired weld metal performance and properties. Negligence to which, the weld metal may suffer from numerous defects and ultimately may result to premature failures of the joint.

2.0 WELDING PARAMETER:

2.1 Current – During arc welding selection of current plays a significant role. Too high a current may cause more spatter, over heating of electrode, porosity, improper bead shape, undercut, burn through, etc and if the current is very low then defects like; lack of fusion, uneven/ convex bead shape, center-line crack, etc may form at the time of welding. Judicious selection of current depends on –

- Diameter of consumables
- Welding positions
- Selection of shielding gas
- Plate thickness & joint gepmetry
- Control on heat input

2.2 Voltage – In arc welding higher voltage is related to higher arc gap (the distance between the tip of the arc and the job) during arcing. Higher arc gap leads the drop to travel a longer distance and thus makes the weld metal more propensive to atmospheric contamination. Considering the characteristics of the welding condition, a proper balance of current & voltage is required to achieve the optimum performance.

2.3 Travel speed – The word travel speed is the movement of the welding head with time. Optimization is done based on welding current, voltage and the joint configurations.

2.4 Shielding gas flow – In gas metal arc welding or flux cored arc welding shielding gas flow of 12-20 liter/ minute are most commonly used. But the actual flow ahead of the gun tip shall be ensured by preventing any leakage in the gas connections/ flow.

3.0 CARBON EQUIVALENT, PRE-HEAT & INTER-PASS TEMPERATURE:

The lion's share of structural fabrication is covered by C-Mn steel and low alloy steel. In general the weldability of these materials is good but a special care of preheating and post weld heat treatment is sometimes necessary to achieve the desired weld quality and service life. Preheating lowers the cooling rate of the weld metal and reduces the magnitude of shrinkage stresses, effectively prevents weld metal and base metal cracking. Extent of total contraction is reduced by 30% for the joints preheated to 200°C compared to similar joints welded at room temperature.

The objective of pre-heating is described as-

1. reduce the level of shrinkage
2. decrease residual stresses
3. prevent formation of hard microstructure in HAZ
4. decrease distortion
5. compensate heat for highly conductive material
6. drive off moisture in the welding vicinity

The pre-weld heat treatment in such grades of steels is estimated by the carbon equivalent (CE) formula. The most widely accepted formula proposed by International Institute of Welding (IIW) is represented as -

$$\mathbf{CE = \%C + \%Mn/6 + \%(Cr + Mo + V)/5 + \%(Ni + Cu)/15}$$

For C-Mn steel (CE = C + Mn/6), the temperature of preheating (PR_{HT}) is calculated as,

$$\mathbf{PR_{HT}\ (°F) = 1000\ (CE - 0.11) + 18t}$$

Where, t is the thickness of the plate in inches.

For low alloy steels, preheat temperature is calculated as per the Seferian formula.

$$\textbf{Preheat temperature (Tp): } = 350\sqrt{(TCE - 0.25)}$$

Where, TCE (Total Carbon Equivalent) = CCE + PTCE, CCE = Chemical Carbon Equivalent and PTCE = Plate Thickness Carbon Equivalent

CCE = %C + %Mn/6 + %(Si + Al)/ 24 + %(Ni + Cu)/15 + %(Mo + V + Nb)/4 + %Cr/5

PTCE = 0.005t * CCE

Where, t = thickness of the plate in mm and PTCE is a function of plate thickness and hardenability of steel.

$$\mathbf{Tp = 350 \sqrt{[CCE\ (1 + 0.005t) - 0.25]}}$$

Inter-pass temperature is the temperature maintained after each run during a multilayer weld deposit. In general, the pre-heat temperature is the upper limit of inter-pass temperature. Inter-pass temperature reduces the cooling rate after welding but too high a temperature drastically lowers down the cooling rate causing coarsening of grains. Coarse grained structure is undesired as it affects the toughness properties especially at temperatures below zero degree celcius.

4.0 POST-WELD HEAT TREATMENT:

Post-weld heat treatment (PWHT) is often required for high CE materials depending on carbon content and section thickness of the base plate. The most important factors to be considered during PWHT are –

- rate of heating
- the maximum temperature to which the weldment is taken
- holding time at that temperature and
- rate of cooling

The PWHT of weld metal is conducted to –

1. relieve residual stresses

2. produce desired microstructure
3. increase ductility and reduce hardness
4. increase resistance to corrosion
5. assist in removal of H_2 from weld metal
6. improve fatigue & impact resistance and reduce notch effect
7. improve machinability and
8. achieve dimensional stability